# CONCISE ENCYCLOPEDIA OF POLYMER SCIENCE AND ENGINEERING

Jacqueline I. Kroschwitz, *Executive Editor*




A Wiley-Interscience Publication
John Wiley & Sons
New York / Chichester / Weinheim / Brisbane / Singapore / Toronto

This text is printed on acid-free paper.



Paper edition published 1998.



**Library of Congress Cataloging in Publication Data:**

Concise encyclopedia of polymer science and engineering / Jacqueline I. Kroschwitz, executive editor.
p. cm.
"Contains all of the subjects covered in the 17 main volumes and the supplement and index volumes of the . . . 2nd edition of the Encyclopedia of polymer science and engineering"—Pref.
"A Wiley-Interscience publication."
Includes bibliographical references.
ISBN 0-471-51253-2 (cloth); ISBN 0-471-31856-6 (paper)
1. Polymers—Dictionaries. I. Kroschwitz, Jacqueline I. II. Encyclopedia of polymer science and engineering.
TP1087.C66 1990 89-70674
668.9'03—dc20 CIP

Printed in the United States of America

10 9 8 7 6 5 4 3 2

## COPOLYMERS

One attraction of styrene as a monomer stems from the wide range of properties attainable by copolymerization. The homopolymer can be improved through copolymerization and still maintain excellent economics. The result is materials as diverse as automobile instrument panels and ion-exchange beads.

### Styrene–Acrylonitrile Copolymers (SAN)

Acrylonitrile-containing resins have gained an important place in the plastics industry. In 1985, the United States produced about 1.1 billion kg of acrylonitrile, 25% of which was used in styrene and rubber-modified styrene copolymers.

### Rubber-modified SAN Copolymers (ABS)

General-purpose SAN copolymers have improved properties when compared with polystyrene, but still fail in a brittle fashion when subjected to sudden, high speed impact (see ACRYLONITRILE POLYMERS). Rubber reinforcement of SAN increases its ability to withstand high speed impact; these materials are called acrylonitrile–butadiene–styrene (ABS) polymers (qv). ABS has the processibility of styrene-based resins and excellent toughness.

### Poly(styrene-*co*-methyl methacrylate)

The properties of styrene–methyl methacrylate (SMMA) copolymers generally fall between those of the individual homopolymers. Thus the weatherability and solvent resistance of this copolymer are superior to those of polystyrene homopolymer. Figure 1 shows that SMMA copolymers do exhibit a substantial weathering advantage when compared with polystyrene. Table 1 lists some physical properties of commercial grades of SMMA resins.

### Poly(styrene-*co*-divinylbenzene)

Divinylbenzene is a diolefinic monomer capable of addition polymerization involving both of its double bonds. In reactions with styrene, at concentrations above about 0.06%, a cross-linked structure is obtained that is no longer thermoplastic, but has particular uses. One of the most important uses of styrene–divinylbenzene copolymer is in ion-exchange beads (see ION-EXCHANGE POLYMERS).

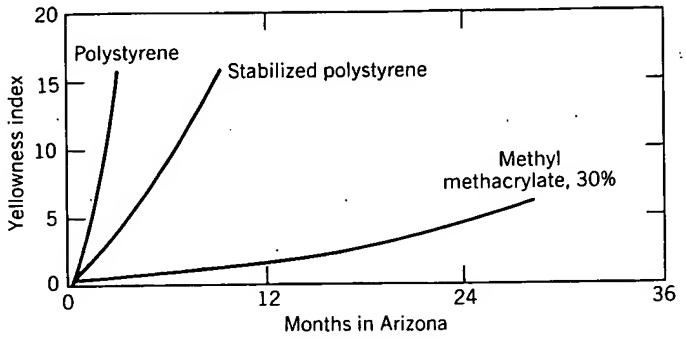


**Figure 1.** Outdoor weatherability of unmodified general-purpose polystyrene, light-stabilized polystyrene, and a 30% methyl methacrylate copolymer (with stabilizers). A higher yellowness index indicates more yellow resin.

### Poly(styrene-*co*-butadiene)

***Random Copolymers.*** The copolymerization of butadiene with styrene results in a product that has a lower $T_g$ than polystyrene and can be vulcanized (cross-linked).

Styrene–butadiene (SB) copolymers can be tailored to fit end-use applications by careful attention to the monomer ratio (including additional monomers), average molecular weight, molecular weight distribution, linearity of molecular structure, extent of gel, cis–trans vinyl group ratios, and distribution of styrene and butadiene units (block vs random copolymers) (see also BUTADIENE POLYMERS). Random SB copolymers are made on a commercial scale by either emulsion or, more recently, solution polymerization methods.

***Block Copolymers.*** Block SB copolymers, made by anionic solution polymerization, have found commercial application because of their thermoplastic and elastomeric property combinations. Morphology studies have revealed that the reversible vulcanization exhibited by some of these elastomers is caused by the phase separation of the styrene blocks into distinct and discrete domains (see ELASTOMERS, THERMOPLASTIC).

**Table 1. Physical Properties of Commercial SMMA Resins**

| | SMMA | | | |
|---|---|---|---|---|
| | Extrusion[a] | Injection molding[b] | TABS[c] | TIPS[d] |
| tensile strength, MPa[e] | 68.2 | 57.2 | 50.5 | 40.8 |
| tensile elongation, % | 5.0 | 2.0 | 30.0 | 60.0 |
| tensile modulus, MPa[e] | 3300 | 3500 | 2600 | 2500 |
| flexural strength, MPa[e] | 116 | 103 | 85 | 67 |
| flexural modulus, MPa[e] | 3300 | 3500 | 3000 | 2200 |
| Izod impact (notched), J/m[f] | 20 | 20 | 107 | 91 |
| specific gravity | 1.13 | 1.09 | 1.10 | 1.11 |
| Rockwell hardnes, M scale | 80 | 64 | 110[g] | |

[a] P-205 UVA (Richardson Polymer Corp.) extrusion grade acrylic polymer.
[b] NAS (Richardson Polymer Corp.) injection-molding grade acrylic polymer.
[c] Magnum CLR-95 (The Dow Chemical Co.) transparent ABS, injection-molding grade.
[d] Experimental resin EX-836 (The Dow Chemical Co.) transparent impact polystyrene, extrusion grade.
[e] To convert MPa to psi, multiply by 145.
[f] To convert J/m to ft-lb/in., divide by 53.38.
[g] Rockwell R scale.